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RODENT CONTROL, RESEARCH NEEDS, AND TECHNOLOGY TRANSFER

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Abstract: Rodents are distributed nearly worldwide; their use of habitats is extensive and varied. Rodent species have ecological, scientific, social, or economic values, but a variety of economic or health problems result from rodent interaction with humans. Control methods include hunting, trapping, toxic baits, sanitation, exclusion, and habitat modification. Research is underway to investigate reproductive inhibition, repellents, and other approaches to reduce rodent damage. Before intiating control, the problem species must be confirmed; its basic biology and ecology understood; the type, time, and amount of damage assessed; and an array of possible control options considered. An integrated pest management program is more likely to meet criteria of efficacy and cost-effectiveness. There is a need for improved technology transfer and technical assistance.

Resumen: Los roedores tienen una distribución casi cosmopolita y su uso de hábitat es extensivo y variado. Todas las especies de roedores tienen valores ecológicos, científicos, sociales o económicos, pero existe una variedad de problemas económicos o de salud que resulta de la interacción de roedores con humanos. En muchas ocasiones, las especies nativas causan serios problemas a la agricultura. Un gran número de géneros han sido implicados en problemas en casi todos los continentes. Los métodos de control incluyen la cacería, el trapeo, cebos tóxicos, higiene, exclusión, modificación de hábitat, o combinación de los anteriores. Actualmente se llevan a cabo investigaciones acerca de la inhibición reproductiva, control biológico, resistencia a plantas naturales, venenos selectivos, repelentes efectivos, y métodos culturales para reducir los daños producidos de roedores. Sin embargo, antes de iniciar cualquier programa de control, la especie problemática debe ser identificada; debe estudiarse su biología y ecología; el tipo, tiempo y cantidad del daño analizado; e incluirse medidas preventivas y mecanismos de retroalimentación, es más factibles que llenen el criterio de eficacia y costo-benefico. Exite una necesidad de mejorar la transferencia de tecnología apoyada por asistencia técnica.

Key words: agriculture, animal damage, rodenticide, rodents, technology transfer.

With over 1,600 species, the order Rodentia has more members than any other order of mammals (Nowak 1991). The distribution of rodents is nearly worldwide; their use of habitats is extensive and varied. Most rodent species are relatively small, secretive, prolific, adaptible, and have continuously growing incisors. All rodent species have ecological, scientific, social, or ecomonic values. Rodents are important in seed and spore dispersal, pollination, seed predation, energy and nutrient cycling, the modification of plant succession and species composition, and as a food source for many predators. Certain species and strains have been bred for decades for use in medical research. Some species serve as a source of food for humans. Certain species have commercial value as furbearers.

A variety of economic or health problems result from rodent interactions with humans: damage to growing crops, seeds, pastures, and trees; damage and contamination of stored foods; damage to structures; and disease transmission. Some of the most familiar problems are caused by the ubiquitous commensal rodents (*Rattus norvegicus*, *R. rattus*, and *Mus musculus*), but native species often cause serious problems to agriculture as well.

Feeding the growing human population requires greater food availability every year, hence it is important that we control or reduce agricultural losses to rodents and other agents (Smythe 1986). We discuss preharvest agricultural losses resulting from native rodents around the world. We consider the genera and species involved and their geographic distribution, the types and extent of damage, the traditional approaches to rodent damage management, some areas of current research, and some problem areas of technology transfer that hinder the establishment of effective rodent damage management programs.

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EXTENT OF THE PROBLEM

Many genera of native rodents have been implicated in agricultural crop damage around the world (Table 1). We follow the terminology of Nowak (1991) for names of genera and species. These genera include large and small body sizes, high and low reproductive potentials, high and low densities, social and asocial behaviors, and terrestrial, fossorial, arboreal, and aquatic habits. In some areas such as Australia, Hawaii and other Pacific Islands, and parts of Southeast Asia, introduced rodents (generally, *Rattus* spp.) are essentially the main

Table 1. Examples of native rodents causing agricultural damage in various parts of the world.

Continent/area	No. genera; examples	Crops damaged	References
North America	19; *Cynomys, Geomys, Marmota, Microtus, Spermophilus, Thomomys*	Grains, alfalfa, flax, cotton, potato, sugar cane, trees	Marsh (1984, 1988)
Central and South America	18; *Ctenomys, Holochilus, Octodon, Oryzomys, Sigmodon, Zygodontomys*	Grains, beans, cotton, sugar cane, potato, cassava, bananas, trees	Elias and Fall (1988), Hilje and Monge (1988), Jackson (1988)
Europe	7; *Apodemus, Arvicola, Clethrionomys, Cricetus, Microtus, Pitymys*	Grains, alfalfa, potato, beets, trees	Lund (1984*a*, 1988)
Africa	42; *Arvicanthis, Mastomys, Meriones, Rhabdomys, Tatera, Thryonomys, Xerus*	Grains, cotton, sugar cane, potato, cassava, groundnut, plantation crops, trees	Fiedler (1988*a*), Smythe (1986), Taylor (1984)
Middle East	9; *Hystrix, Meriones, Microtus, Nesokia, Psammomys, Spalax*	Grains, peanuts, root crops, vegetables, dates, tree	Moran and Keidar 1993
Asia	23; *Arvicola, Bandicota, Spermophilus, Cricetulus, Meriones, Microtus, Nesokia, Rattus, Tatera*	Grains, cotton, potato, sugar cane, vegetables, groundnut, banana, mango, pineapple, trees	Prakash (1984), Prakash and Mathur (1988), Zhi and Cheng-Xin (1984)
Southeast Asia/Pacific Islands	6; *Bandicota, Callosciurus, Mus, Rattus*	Grains, root crops, cocoa, sugar cane, oil palm, coconut, pineapple	Benigno and Sanchez (1984), Hoque et al. (1988)

problem rodents (Armstrong 1984, Tobin et al. 1990). They can cause significant damage to field crops in some cases (Tobin et al. 1990). In the northern latitudes, ground and tree squirrels and voles are often primary problem species. Pocket gophers are widespread in North and Central America, although ecological equivalents (e.g., *Bathyergus*, and *Spalax*) cause problems on many other continents. Jirds and gerbils and several species of rats are major problem rodents in Africa, the Middle East, and Asia.

Virtually all parts of plants are damaged by this array of rodent genera. Additionally, a wide array of crops are damaged, including grains, root crops, vegetables, fruits, and trees (Table 1). Although most of these rodent species are capable of feeding on a variety of native plants, they cause economic damage primarily in monocultures of concentrated agricultural crops such as rice (Elias 1988, Quick 1991).

The amount of crop losses to rodents varies widely by area, crop, rodent, season, and year; often the timing and extent of damage is also poorly documented (Fall 1991, Fiedler et al. 1991). It is not uncommon for yields to be reduced by ≥ 10% in various crops (Hoque et al. 1988, Key 1990, Fiedler et al. 1991). During rodent population eruptions, damage can exceed 30% of yields (Richards 1986, Prakash 1988); in some cases, widespread total loss of crops has occurred (Fiedler 1988*b*).

METHODS TO REDUCE RODENT DAMAGE

A great variety of methods have been, or are being, used around the world to help reduce crop losses to rodents (Table 2). Managing rodent damage in the forest and field is typically more difficult, with fewer options available, than for situations around human habitation, structures, and facilities. Many of the methods used (Table 1) have not proven to be very effective or economical for rodent control. For a method to receive widespread and repeated use, it must be effective, inexpensive, legal, able to be used safely by humans, environmentally benign, and socio-politically acceptable.

Rodent control in forests and agricultural fields has traditionally relied on toxicants or kill-trapping (Zhi and Cheng-Xin 1984, Richards 1986, Hoque and Saxena 1988, Fiedler and Fall 1993). In some cases, use has been reduced because of social or environmental concerns or because rodents have become resistant or tolerant to the rodenticides being used (Lund 1984*b*, Tobin et al. 1990, Wood and Chung 1990). Improper uses or use of adulterated rodenticides have also reduced effectiveness. In some cases, when 1 species of rodent is successfully controlled, ≥1 other species will increase in numbers and begin causing significant damage; hence the need to understand basic rodent ecology and species interactions, and to focus efforts on managing economic damage (Prakash 1988, Tobin et al. 1990, Wood and Chung 1990).

The mainstay rodenticides are a relatively few

Table 2. Methods and techniques for rodent control that have been suggested, tested, or used for various rodent problems (Fall 1991).

Physical	Chemical	Biological	Other
Rodent proof construction	Baits/baiting systems	Harborage removal	Appeasement
Passive barriers	Glues	Immunogens	Insurance
Electric barriers	Poison sprays	Habitat modification	Bounties
Drift fences	Poison moats	Cultural practices	Harvest
Trapping	Tracking powder	Crop timing	Compensation
Flooding burrows	Tracking greases, gel	Crop diversification	
Drives	Repellents	Buffer crops	
Hunting	Attractants	Parasites	
Clubbing	Aversive agents	Diseases	
Frightening devices	Plant systematics	Predators	
Flame throwers	Sterilants	Ultrasonics	
Burrow destruction	Fumigation	Biosonics	
Habitat destruction	Psychotropic drugs	Resistant plants	
		Lethal genes	

acute toxicants and an array of anticoagulant toxicants (Savarie 1991). Rodenticide misuse can be hazardous to humans, pets, livestock, and nontarget wildlife (Fall 1991), but measures can be taken to greatly reduce hazards (O'Brien 1986).

Although nonlethal approaches have been less often applied (and perhaps less often effective in reducing damage), there are some examples of these types of damage reduction programs. Squirrel damage to conifer plantations was reduced by cultural methods such as weeding and thinning (Kuo and Liao 1986). Vole damage to trees was reduced with the use of predator odors (Sullivan et al. 1990). It also appears that the influx of rats into crop fields can be reduced by the use of nonlethal electric fences (Fall 1991).

Table 3. Some current rodent damage research areas and technology transfer needs.

Research areas
Censusing/marking methods
Timing of control
Slowing/preventing reinvasion
Oral delivery systems
Reproductive inhibition
Repellents, predator odors
Physical barriers
New or improved traps
Toxicant re-registration trials
New toxicant trials
Technology transfer needs
Initial cash investment
Sociocultural acceptability
Logistical support, infrastructure
Tiered organizational structures
Inexpensive/reliable equipment and supplies
Trained personnel and information availability at the local level
Integrated pest managment
Appropriate use of media
Surveillance of situation

More research is needed to understand the nature of rodent damage to crops and ways in which to reduce that damage (Howard 1988). The evaluation of existing methods still needs to be conducted in many places. The ability to develop new, safe, and effective methods of rodent damage management will depend on many factors in addition to the results of lab, pen, and field trials: funding, actions by regulatory agencies, interest and involvement by commercial developers of methods/products, and pressures by agricultural producers and interest groups (Table 3).

IMPLEMENTING DAMAGE REDUCTION PROGRAMS

Rodent control received less attention than the control of other agricultural pests such as weeds, insects, and plant diseases (Elias 1988). The technical ability to control rodent populations exists, but appropriate transfer and implementation of that technology is needed (Smythe 1986, Hoque and Saxena 1988, Fall 1991, Quick 1991, Fiedler and Fall 1993). The difficulties of organizing, implementing, and sustaining rodent damage management programs have been reported from around the world (Key 1990, Tobin et al. 1990, Fiedler and Fall 1993).

The basic strategies of rodent damage management include either tolerance of damage, management of damage, or eradication/exclusion of rodents (Fiedler and Fall 1993). Futhermore, a management program needs objectives; a plan, the implementation of actions, and an evaluation of results. Part of the plan involves decisions on who will do the action(s), where the action(s) will be done, and which specific methods to apply (Fiedler et al. 1991, Quick 1991). A feedback mechanism is necessary to relate actions to results and accomplishment of specific objectives; i.e., preventing crop damage. Documentation of actions and results will assist in future decision-making and planning. Integrated pest management involves the incorporation of these considerations and the use of com-

binations of methods in proactive and reactive ways to avoid serious rodent problems (Fall 1991, Fiedler and Fall 1993). Vertebrate damage management training manuals can be a significant aid in control programs. Additionally, successful implementation of the program and reduction in losses to rodents will require overcoming a number of other difficulties of technology transfer (Table 3). Unfortunately, most programs are a single effort and, consequently, not very effective (Fall 1991). The real difficulty is in sustaining the program over time, given the changes in priorities, funding, governments, and other related matters (Hoque and Saxena 1988, Fiedler and Fall 1993).

Rodent populations, and the damage they cause, will need to be managed successfully if the human population is to continue to grow and standards of living maintained or improved. The continued efforts of the research community, public and private sectors, and national and international agencies will be required to meet the challenges.

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